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(54) Title: CODE DIVISION MULTIPLE ACCESS COMMUNICATION

(57) Abstract: In a CDMA communication system, stations (4a, 4b, 4c) operating in the same area transmit to a receiver (2a) using a common carrier frequency. Each station (4a, 4b, 4c) transmits a plurality of bits in parallel using orthogonal spreading signals. These spreading signals are used by the stations (4a, 4b, 4c) in time-offset manner so that the transmissions from the stations (4a, 4b, 4c) are mutually orthogonal. The spreading signals may be generated by phase modulating a common spreading sequence so that the spectra of the spreading signals rotate at different rates.

Code Division Multiple Access Communication

Field of the Invention

The present invention relates to code division multiple access communication.

Background to the Invention

Code time division multiple access (CTDMA) has been proposed for cellular communications systems, for example mobile phone networks. In CTDMA systems, users in the same cell are allocated the same spreading code and respective time offsets. Although the users are using the same spreading code, orthogonality is preserved because each user's use of the spreading sequence is time-shifted relative to the other users' use of it.

Under ideal conditions, many stations can use the same carrier frequency and spreading sequence because a one-chip offset between stations is sufficient to provide orthogonality. However, in real situations, signals often follow multiple paths of differing lengths between the transmitter and receiver. This causes interference when the path delay spread is greater than the spreading sequence offsets between users because the spreading sequence of the delayed signal from one station can become aligned with that of another at a receiver.

The present invention is not limited in its application to cellular mobile phone networks and is applicable in any situation when a plurality of transmitters must operate in the same area.

Summary of the Invention

The present invention makes use of the fact that mutually orthogonal spread spectrum signals from a common source suffer virtually no degradation of orthogonality unlike signals from different sources which are prone interference due to different multipath effects and amplitude variations. Consequently, differently spread signals from the same source can generally be more reliably discriminated than signals from different sources. In other words, the interference between signals transmitted from the same source on the same carrier is independent of

multipath and fading effects. An additional gain is achievable because the interactions between the signals can be reliably predicted and the detection process modified accordingly.

According to the present invention, there is provided a method of transmitting a signal, the method comprising:-

providing digital data to be transmitted to a remote station as a plurality of parallel bitstreams;

phase modulating said bitstreams with respective orthogonal or substantially orthogonal spectrum spreading signals to produce a plurality of modulating signals;

phase modulating respective instances of a carrier with said modulating signals to produce a plurality to modulated carrier instances; and

summing the modulated carrier instances and transmitting the result of said summation.

Each spreading signal may be produced by phase modulating a common finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence. The effect of this is that the spectrum of each spreading signal rotates at a different rate. Not all of the spreading signals need to have rotating spectra and one of the spreading signals may simply comprise the common spreading sequence.

Preferably, the period of the spreading sequence is the same as the symbol period and the symbols are aligned with the spreading sequence. In other words each transmitted bit is spread by the whole spreading sequence.

The present invention may be used to send two or more signals in parallel. For instance a video signal could be send four bits at a time using four spreading signals and an accompanying audio signal could be sent with another spreading signal. Preferably, however, said bitstreams comprise bits of a single digital signal such that groups of bits of said single digital signal are transmitted in parallel.

According to the present invention, there is provided a transmitter comprising:

a source of digital data to be transmitted to a remote station as a plurality of parallel bitstreams;

first means, for instance a digital signal processor, for phase modulating said bitstreams with respective orthogonal or substantially orthogonal spectrum spreading signals to produce a plurality of modulating signals;

second means, for instance analogue phase modulators, for phase modulating respective instances of a carrier with said modulating signals to produce a plurality to modulated carrier instances; and

a summer for summing the modulated carrier instances.

Preferably, the first means comprises means for producing each spreading signal by phase modulating a common finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence. However, it is more preferred that the first means comprises means for producing one of the spreading signals by generating a finite spreading sequence and producing the other spreading signals by phase modulating said finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence.

The cyclic signals are preferably substantially sinusoidal and are more preferably stepped sine waves, each step having the same duration as chips of said spreading sequence.

Preferably said spreading sequence *c[.]* is derived from a first code *a[.]* and a second code *b[.]* according to

$$c[n] = \left[a[0]\vec{b}, a[1]\vec{b}, \ldots, a[M-1]\vec{b}\right].$$

which enables a relatively simple receiver design which will become apparent from the description of the exemplary embodiment.

Preferably, the Fourier transforms of the first and second codes satisfy:

$$s[t] \leftrightarrow S(e^{j\omega}) \neq 0 \text{ for all } \omega$$

where s and S represent the first and second codes in the time and frequency domains respectively.

Preferably, the source of digital data signals includes means, for instance a digital signal processor, for generating said bitstreams from a single digital signal such that groups of bits of said single digital signal are transmitted in parallel.

A transmitter according to the present invention may be employed in a mobile phone or a base station of a mobile phone network.

According to the present invention, there is provided a method of receiving a signal produced by a method according to the present invention, the method comprising the steps of:-

producing a baseband signal, comprising components corresponding to the modulating signals, from a received rf signal; and

processing the baseband signal by processes adapted to extract the data from each of the modulating signals.

Preferably, at least all but one of said processes comprises:-

phase modulating the baseband signal by the inverse of a respective one of said cyclic signal to produce a first signal;

phase modulating instances of the first signal by respective cyclic signals of the form $e^{j2\pi nP/L}$ where P comprises the set of values in the range 0, ... , L-1, and L is the length of the second code to produce L second signals;

filtering each of said second signals with a filter having a transfer function which is the inverse of the first code to produce respective third signals;

correlating the third signals with corresponding reference signals and summing the results of the said correlations.

In this context, "inverse" does not refer to the logically-inverted binary sequence by the reciprocal of the function (time or frequency domain) defining the code.

A method according to the present invention includes mapping the outputs of said processes onto a transmitted parallel bit pattern using a maximum likelihood algorithm and outputting said parallel bit pattern. In this way, account may be taken of interference between the parallel bitstream signals.

The data bits extracted by said processes may combined into a single data signal or kept as separate signals.

According to the present invention, there is provided a receiver for receiving a signal produced by a method according to the present invention, the receiver comprising:-

rf processing means for producing a baseband signal, comprising components corresponding to the modulating signals, from a received rf signal; and

processing means, for example a digital signal processor, for processing the baseband signal by processes adapted to extract the data from each of the modulating signals.

Preferably, at least all but one of said processes comprises:-

phase modulating the baseband signal by the inverse of a respective one of said cyclic signal to produce a first signal;

phase modulating instances of the first signal by respective cyclic signals of the form $e^{j2\pi nP/L}$ where P comprises the set of values in the range 0, ... , L-1, and L is the length of the second code to produce L second signals;

filtering each of said second signals with a filter having a transfer function which is the inverse of the first code to produce respective third signals;

correlating the third signals with corresponding reference signals and summing the results of the said correlations.

Preferably, the processing means is configured for mapping the outputs of said processes onto a transmitted parallel bit pattern using a maximum likelihood algorithm and outputting said parallel bit pattern.

Preferably, the processing means is configured to combine the extracted data bits into a single data signal.

A receiver according to the present invention may be employed in a mobile phone a base station of a mobile phone network.

According to the present invention, there is provided a mobile phone network including a base station, having a receiver according to the present invention, in communicative relation to a plurality of mobile phones having transmitters according to the present invention, wherein the mobile phones employ the same carrier frequency and spreading signals for communication with the base station, each mobile phone applying the spreading signals in a time offset manner relative to the use of the spreading signals by each of the other mobile phones. The present invention is particularly advantageous for mobile-to-base station transmission and alternative schemes may be employed for base-to-mobile station transmission.

Brief Description of Drawings

Figure 1 illustrates part of a cellular mobile telephone network;

Figure 2 is a block diagram of a base transceiver station of the network shown in Figure 1;

Figure 3 is a block diagram of a mobile station of the network shown in Figure 1;

Figure 4 is a block diagram illustrating the generation of parallel data signals in a transmitter according to the present invention;

Figure 5 is a block diagram illustrating spectrum spreading and modulation in a transmitter according to the present invention;

Figure 6 illustrates the transmissions from three mobile stations in the same cell of the network shown in Figure 1;

Figure 7 is a block diagram of part of the receiver of a mobile phone network base station according to the present invention;

Figure 8 is a block diagram of a despreading detector as used in the receivers of the base stations and mobile station in Figure 1

Figure 9 is a block diagram of a channel of a despreading detector as shown in Figure 8; and

Figure 10 is a diagram illustrating the advantages of the present invention over conventional CTDMA.

Detailed Description of the Preferred Embodiment

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings.

Referring to Figure 1, a cellular mobile telephone network comprises a plurality of cells 1a, 1b, 1c defined by the radiation patterns of respective base transceiver stations 2a, 2b, 2c. The base transceiver stations 2a, 2b, 2c are connected to a common base station controller 3.

First to seventh mobile stations 4a, ... , 4g, are located in the cells 1a, 1b, 1c and each mobile station 4a, ... , 4g can communicate with the base transceiver station of the cell 1a, 1b, 1c in which it is located.

The base station controller 3 controls the operation of the base transceiver stations 1a, 1b, 1c and is connected to a mobile service switching centre (not shown) for the routing of calls.

Referring to Figure 2, the first base transceiver station 2a comprises a controller 5, a transmitter 6, a receiver 7, a first digital signal processor 8, a second digital signal processor 9 and a base station controller interface 10. The base station controller interface 10 receives signals from the base station controller 3 and routes them either to the controller 5, in the case of control signals, or to the first digital signal processor 8 in the case of speech signals. The base station controller interface 10 also sends control signals from the controller 5 and speech signals from the second digital signal processor 9 to the base station controller 3.

The first digital signal processor 8 receives speech signals from the base station controller interface 10 and processes them to produce a modulating signal which it provides to the transmitter 6. The transmitter 6 modulates a carrier with the modulating signal and transmits it to a mobile station 4a, 4b, 4c.

The receiver 7 receives signals from the mobile stations 4a, 4b, 4c and outputs baseband signals to the second digital signal processor 9 which processes them to extract the transmitted speech signal data and control data which is then sent to the base station controller 3 by the base station controller interface 10.

The tuning of the transmitter 6 and of the receiver 7, if required, is controlled by the controller 5.

The construction of the second and third base transceiver stations 2b, 2c is substantially identical to that of the first base transceiver station 2a.

Referring to Figure 3, the first mobile station 4a comprises an antenna 11, an rf subsystem 12, a baseband digital signal processing subsystem 13, an analogue audio subsystem 14, a loudspeaker 15, a microphone 16, a controller 17, a liquid crystal display 18, a keypad 19, memory 20, a battery 21 and a power supply circuit 22.

The rf subsystem 12 contains the rf circuits of the mobile station's telephone's transmitter and receiver and a frequency synthesiser for tuning the mobile station's transmitter and receiver. The antenna 11 is coupled to the rf subsystem 12 for the reception and transmission of radio waves.

The baseband digital signal processing subsystem 13 is coupled to the rf subsystem 12 to receive digital baseband in-phase and quadrature signals therefrom and for sending baseband modulation signals thereto. The baseband digital signal processing subsystem 13 includes codec functions that are well-known in the art and function peculiar to the present invention which are described in detail below.

The analogue audio subsystem 14 is coupled to the baseband digital signal processing subsystem 13 and receives demodulated audio therefrom. The analogue audio subsystem 14 amplifies the demodulated audio and applies it to the loudspeaker 15. Acoustic signals, detected by the microphone 16, are pre-amplified

by the analogue audio subsystem 14 and sent to the baseband digital signal processing subsystem 13 for coding.

The controller 17 controls the operation of the mobile station 4a. It is coupled to the rf subsystem 12 for supplying tuning instructions to the frequency synthesiser and to the baseband digital signal processing subsystem 13 for supplying control data and call management data for transmission. The controller 17 operates according to a program stored in the memory 20. The memory 20 is shown separately from the controller 17. However, it may be integrated with the controller 17. A timer for triggering interrupts is also provided by the controller 17.

The display device 18 is connected to the controller 17 for receiving control data and the keypad 19 is connected to the controller 17 for supplying user input data signals thereto.

The battery 21 is connected to the power supply circuit 22 which provides regulated power at the various voltages used by the components of the mobile telephone. The positive terminal of the battery 21 is connected to an analogue-to-digital converter (ADC) input of the controller 17 for battery life monitoring.

The other mobile stations 4b, ... , 4g are similarly constructed.

The present invention is particularly concerned with the generation of modulating signals and the demodulation of received signals. Consequently, the following description will focus on these aspects and it can be assumed that other functions of the mobile stations 42, ... , 4g and base transceiver stations 2a, 2b, 2c are conventional.

Transmission from the First Mobile Station to the First Base Transceiver Station

Referring to Figure 4, during a call, speech detected by the microphone 16 is pre-amplified by the analogue audio subsystem 14 and then digitised to produce a stream of digital samples. The digital samples are then encoded by the baseband digital signal processing subsystem 13 in a conventional manner to produce a stream

of linear prediction coefficients which are in turn channel coded in a conventional manner to reduce the transmission bandwidth required and/or provide error correction.

The first mobile station 4a will have been allocated a spreading sequence, common to all mobile stations in the same cell, and a transmission offset time, relative to a reference frame for the cell 1a in which the first mobile station 4a is camped and which is unique to the first mobile station 4a, by the base station controller 3. The information will have been communicated to the mobile station 4a in a control channel when it entered the cell 1a in which it is currently camped.

The spreading sequence is defined by two component sequences a[.] and b[.]. In the present example, a[.] comprises {-1, -1, 1} and b[.]comprises {-1,-1,-1,-1,-1,1,1,-1,-1,1,-1,1,-1}. The actual spreading sequence (*c[n]*) is given by: -

$$c[n] = \left[a[0]\vec{b}, a[1]\vec{b}, \ldots, a[M-1]\vec{b}\right]$$
$$= \{1,1,1,1,1,1,-1,1,1,-1,1,-1,1,1,1,1,1,1,1,-1,1,1,-1,1,-1,1,-1,-1,-1,-1,-1,1,1,-1,-1,1,-1,1,-1\}$$

where M is 3, i.e. the number of elements in *a[.]*.

c[n] is represented in the mobile phone 4a by the binary sequence 11111001101011111001101010000011001010.

The spreading sequence can be used in L forms which are subject to different phase modulations for transmitting L bits of the channel coded signal in parallel. L is the number of elements in *b[.]*. The set of spreading sequences is defined by: –

$$c_f[n] = c[n]e^{j2\pi\left(\frac{fn}{N}\right)}$$

where f = 0, ..., 12, i.e. L-1, and n = 0, ..., ML-1 and N = ML.

Thus, for each symbol, the spreading sequence is in effect phase modulated by f cycles of a stepped sine wave. Thus, when f is 0, no phase modulation is applied but if f is 2, for example, the spreading sequence is phase modulated by a stepped sine wave having a period which is half of the symbol period.

In the present example. values of *f* of 0, 1, 2, 3 are used. However, other sets of values for *f* such as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, which is the largest usable set in the present example, or 0, 2, 4, 6, for example, could be used.

It has been discovered that the peak to average power ratio (PAPR) for a transmitter according to the present invention is a complex function of the spreading code and the values of *f* used and that certain values of *f* are associated with high peak power values which adversely affect the overall PAPR. These can be determined experimentally and avoided when selecting values of *f* for a transmitter.

The coded digital speech signals are combined with control bits. These bits are divided into four parallel bitstreams $M_0(t)$, $M_1(t)$, $M_2(t)$, $M_3(t)$.

Referring to Figure 5, the means for modulating a carrier with the four bitstreams $M_0(t)$, $M_1(t)$, $M_2(t)$, $M_3(t)$ comprises first to fourth exclusive-OR gates 31, 32, 33, 34, a sequence generator 35 for outputting the spreading sequence, first, second and third phase modulators 36, 37, 38 for phase modulating the output of the sequence generator 35 by different spectrum rotating functions $e^{j2\pi(fn/N)}$, first to fourth pulse shapers 39, 40, 41, 42 for shaping the outputs of respective exclusive-OR gates 31, 32, 33, 34, fourth to seventh phase modulators 43, 44, 45, 46 for phase modulating a carrier from an oscillator 47, implemented by the mobile station's synthesiser, with the outputs of the pulse shapers 39, 40, 41, 42, a summer 43 for combining the outputs of the fourth to seventh phase modulators 44, 45, 46, 47 and a class A power amplifier 48. The outputs of the sequence generator 35 and the first to third phase modulators 36, 37, 38 are applied to inputs of respective exclusive-OR gates 31, 32, 33, 34. The other inputs of the exclusive-OR gates 31, 32, 33, 34 receive respective ones of the four bitstreams $M_0(t)$, $M_1(t)$, $M_2(t)$, $M_3(t)$.

It will be appreciated that the exclusive-OR gates 31, 32, 33, 34, the sequence generator 35, the first to third phase modulators 36, 37, 38 and the pulse shapers 39, 40, 41, 42 are implemented computationally in the baseband digital signal processing subsystem 13.

The operation of the system shown in Figure 5 will now be described. The four bitstreams $M_0(t)$, $M_1(t)$, $M_2(t)$, $M_3(t)$ are exclusive-ORed with respective spreading sequences having different phase characteristics. The four resulting modulation bit streams $m_0(t)$, $m_1(t)$, $m_2(t)$, $m_3(t)$ are then

$$m_0(t) = M_0(t)c[n]$$
$$m_1(t) = M_1(t)c[n]e^{j2\pi\left(\frac{1n}{N}\right)}$$
$$m_2(t) = M_2(t)c[n]e^{j2\pi\left(\frac{2n}{N}\right)}$$
$$m_3(t) = M_3(t)c[n]e^{j2\pi\left(\frac{3n}{N}\right)}$$

where $n = (t \text{ div } T_c) \bmod N$,
$M_i(t)$ is the ith data bitstream
and T_c is the chip period.

The modulation bit streams $m_0(t)$, $m_1(t)$, $m_2(t)$, $m_3(t)$ are then pulse shaped using a square root cosine form, with a roll-off factor of 0.5, and then used to BPSK modulate respective carrier signals from the same source to produce four modulated carriers which are then summed and transmitted. The resulting signal is of non-constant amplitude and therefore a class A power amplifier 48 is required for amplifying it for transmission.

The gain of the amplifier 48 is controlled by the controller 17 on the basis of the signal strength of signals received from the first base transceiver station

The sequence output by the sequence generator 35 is synchronised with the cell's reference time frame but offset by the offset allocated to the mobile station 4a. In the present example, the offsets available for mobile station 4a, 4b, 4c using the spreading sequence *c[n]* are 0, $L.T_c$ and $2L.T_c$.

Reception at the First Base Transceiver Station

Referring to Figure 6, the signals (a), (b), (c) from the first, second and third mobile stations 4a, 4b, 4c use the same carrier frequency, spreading sequence and *f* values. However, at the first base transceiver station 2a, the symbols of the second mobile station's signal lag those of the first mobile station's signal by $L.T_c$. Similarly, the symbols of the third mobile station's signal lag those of the first mobile station's

signal by $2L.T_c$. A timing advance mechanism is employed by the mobile stations 4a, 4b, 4c so that their transmissions are received at the first base transceiver station 2a aligned with the cell reference time frame.

Referring again to Figure 2, the signals from the first, second and third mobile stations 4a, 4b, 4c are received by the receiver 7 and down converted to baseband and output as in-phase and quadrature values to the second digital signal processor 9.

Referring to Figure 7, the second digital signal processor 9 computationally implements first, second and third despreading detectors 51, 52, 53 for respective mobile stations 4a, 4b, 4c. The despreading detectors 51, 52, 53 are synchronised with the cell reference time frame with the second and third despreading detectors lagging the first by $L.T_c$ and $2L.T_c$.

Referring to Figure 8, the first despreading detector 51 comprises first, second, third and fourth channels 54, 55, 56, 57 for decoding respective one of the parallel bitstreams of the received signal from the first mobile station 4a and a decision processor and format converter 58 for converting the 4-bit wide parallel format in which the bits are transmitted, into the format (e.g. serial or 8- or 16- bit parallel) required for subsequent processing such as channel and speech decoding.

Referring to Figure 9, the first channel 54 of the first despreading detector 51 comprises a phase modulator 61 for removing any phase modulation impressed on the spreading sequence at the mobile station 4a. Following the phase modulator 61, the signal path divides into L parallel branches 62a, 62b, 62c. Each branch comprises a respective first multiplier 63a, 63b, 63c, a respective filter 64a, 64b, 64c, a respective second multiplier 65a, 65b, 65c and a respective integrator 66a, 66b, 66c. The outputs of the branches 62a, 62b, 62c are input to a summer 67.

The first multipliers 63a, 63b, 63c multiply the output of the phase modulator 61 by a signal of the form $e^{j2\pi nP/L}$ where P is the index of the branch and is in the range 0, ..., L-1. The outputs of the first multipliers 63a, 63b, 63c are filtered by respective

ones of the filters 64a, 64b, 64c. The filters 64a, 64b, 64c all have the same transfer function *v[n]* which is the inverse of the sequence a[.] and aperiodic. In other words, *v[n]* is the inverse of the filter whose transfer function is such that is would produce the sequence a[.] in response to an impulse. Consequently, *v[n]* produces an impulse when the sequence a[.] is input.

The second multipliers 65a, 65b, 65c and the integrators 66a, 66b, 66c combine to form respective matched filter/correlators. The sequences *u*[n, P]* applied to the second multipliers 65a, 65b, 65c are the product of the spreading sequence (*c[n]*) and the transfer function (*v[n]*) and the respective phase rotation function $e^{j2\pi nP/L}$ for each branch. Thus,

$$u^*[n;P] = c[n]v[n]e^{j2\pi n\frac{P}{L}}$$

A consequence of this is that these sequences (*u*[n, P]*) are independent of the sequence *a* and determined by the sequence *b*.

v[n] is real valued and of infinite duration with exponentially decreasing magnitude. However, in practice it is truncated without appreciable loss of performance. *u*[n;P]* can also be truncated to a finite length and the length actually required is much shorter than the truncated length of *v[n]* resulting a correlator that is less complicated that the inverse filter.

The outputs of the integrators 66a, 66b, 66c are summed by the summer 67 and the peak output value, occurring in a window in which a pulse signal is expected to occur on the basis of the first mobile station's time offset and path conditions, is determined by a peak detection process 68.

The value of the peak could simply be compared with a threshold to determine whether the received bit is a 1 or a 0. However, in order to reduce the effect of cross-talk between the parallel bitstreams making up the transmission from the first mobile station 4a, the outputs of the four channels 54, 55, 56, 57 are processed together by the decision processor and format converter 58.

The decision processor and format converter 58 has a model of the expected outputs of the channels for each possible transmitted four-bit value, allowing for interference between the four bitstreams, which it modifies on the basis of channel estimations that are repeatedly made. The outputs of the four channels 58 are compared to the modified predicted outputs, e.g. using a least mean squares algorithm, and four bits providing the model having the best match to the received signal are output in the appropriate format. The output signal is then decoded in a conventional manner to extract and reproduce the original speech signal and any control data transmitted from the first mobile station 4a.

Chip synchronisation and channel estimation are obtained by means of periodically transmitted training symbols, which are included with the speech data transmitted by the mobile stations 4a, 4b, 4c. In order to avoid interference between mobile stations, mobile stations whose relative offset is less than the maximum delay of any channel are given orthogonal training sequences of length L. The sequences can be reused by mobile stations whose transmissions are offset by more than the maximum channel delay.

The second and third despreading detectors 52, 53 are substantially identical to the first despreading detector 51 and operate in the same manner save that their timing is of set by LT_c and $2LT_c$ respectively.

Transmission from the First Base Transceiver Station

Transmission from the first base station 2a is substantially the same as transmission from the first mobile station 4a, save that the summer 43 (Figure 5) is adapted to combine phase modulated signals from additional sources. All of the modulating signals are produced by the first digital signal processor 7. The phase modulated signals all have the same carrier frequency and spreading sequence and differ only in the timing of the sequence start. The signals for the first mobile station 4a have a zero offset relative to the reference frame for the spreading sequence, the signals for the second mobile station 4b have an offset of LT_c and the signals for the third mobile station 4c have an offset of $2LT_c$.

Reception at the First Mobile Station

Referring again to Figure 3, the baseband digital signal processing subsystem 13 is programmed to implement a despreading detector as shown in Figure 8. The despreading detector operates in the same manner as those of ~~the~~ first base transceiver station 2a as described above.

Signals received by the first mobile station 4a are converted to baseband by the rf subsystem 12 and then processed by the baseband digital signal processing subsystem 13 to extract speech for output by the loudspeaker 16 and control signals which are sent to the controller 17.

Referring to Figure 10, waveforms (a), (b) and (c) represent the envelopes of the outputs of the despreading detectors of the first base transceiver station 2a in the time domain for multipath signal from the first, second and third mobile stations 4a, 4b, 4c. It can be seen that the delayed signal effects have substantially disappeared before a four-bit group of another transmission is detected. Thus, there is very little intracell interference.

Waveforms (d) and (e) are the responses of conventional CTDMA receivers to two multipath signals under the same propagation conditions. It can be seen that there is a limit to the time offset between the transmissions if the delayed transmissions from one station are not to interfere with the transmissions of the other. In the example shown, by applying the present invention three stations can share the same resources as two using conventional CTDMA and at the same time obtain reduced intracell interference.

In the system described above:-

(a) four of a possible L orthogonal codes, specified by $\{f_i\}=\{i+\ell * M\}$ ($\ell = 0,\ldots L-1$) for i∈[0, M-1]), are used to transmit up to 4 data bits in parallel for a user in the ith cell (up to L bit may be transmitted in parallel);

(b) users within one cell share the same spreading sequence but are time-offset by at least L chips, bit-by-bit cyclically, to avoid or reduce intracell interuser interference;

(c) M orthogonal spreading sequences specified by $i=0,\cdots M-$ in $\{f_i\}=\{i+\ell^*M\}$ are used for respective cells.

The choice of the number of bits transmitted in parallel depends on balancing the desire for the maximum number of concurrent transmissions with receiver complexity.

Therefore with $\{f_i\}=\{i+\ell^*M\}$ ($\ell = 0,\ldots L-1$) (i∈[0, M-1]), the users in cell i are specified by the same phase shift set (i.e. values of *f*) for multicode transmission of up to L bits in parallel, and are time offset by at least L chip periods cyclically at the symbol level. The users of different cell are separated by using different spreading sequences which are orthogonal. In the example given, its is the *a* sequence that differs between cells, the *b* sequence being the same. It can be seen that this simplifies receiver design since only *v[n]* needs to be changed when a mobile station moves from one cell to another. In practice this simply involves changing parameters in the software routine implementing *v[n]*. The length of the tiered code *a[.]* and *b[.]*, together with the chip rate, form the degrees of freedom for a system design.

With a system according to the present invention, the serial-to-parallel-converted data streams of any user are spread by complex codes, corresponding to a group of orthogonal codes. These parallel data stream can be detected using maximum likelihood detector (MLD) at the receiver, for which a RAKE combiner can be also applied for combining the power of a few paths. Whilst users within one cell are separated by a cyclic time offset, as in CTDMA, different groups of orthogonal codes are used in different cells. The parallel transmission compensates for the loss of spectrum efficiency due to the required time offset between users.

An example of MLD will now be described. The receiver digital signal processor is programmed to determine the value of a data bit according to the rule:

$$e^2 = \min_{\hat{\bar{D}}} \left| \bar{\rho} - HR\hat{\bar{D}} \right|^2$$

where

$$\overline{D} = [d[0], d[1], \ldots, d[L-1]]^T$$

$$H = \begin{bmatrix} \overline{H}^T[i;0] & 0 & 0 & 0 \\ 0 & \overline{H}^T[i;1] & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \overline{H}^T[i;L-1] \end{bmatrix}$$

$$R = \begin{bmatrix} \overline{R}[0] & \overline{R}[1] & \cdots & \overline{R}[L-1] \\ \overline{R}[-1] & \overline{R}[0] & \cdots & \overline{R}[L-2] \\ \vdots & \vdots & & \vdots \\ \overline{R}[-L+1] & \overline{R}[-L+2] & \cdots & \overline{R}[0] \end{bmatrix}$$

$$\overline{H}[i;l] = \left[h^{(i)}[\gamma] e^{-j2\pi \frac{i+lM}{LM}(\gamma+\tau_1-\tau_2)} \right]^T \text{ for } \gamma = 0,1,\ldots,\varsigma$$

$$\overline{R}[l] = \left[\sum_i b[l] b[l+\gamma+\tau_1(\mathrm{mod})L-\tau_2(\mathrm{mod})L)] e^{j2\pi \frac{l}{L} i} \right]^T \text{ for } \gamma = 0,1,\ldots,\varsigma$$

$\overline{d}$ is the transmitted data,
V represents all possible combinations of bits transmitted in parallel,
ρ is the decoder output,
H is the channel responds.

It will be appreciated that receiving systems embodying the present invention may employ antenna diversity.

In embodiments of the present invention, phase modulated versions of a common spreading sequence provide a family of good invertable sequences. For a tiered code with components *a[.]* of length M and *b[.]* of length L, M orthogonal groups are obtained, each consisting of L orthogonal spectra. Unlike conventional DS-CDMA systems, users are separated in time and can therefore share the same spreading sequence. Up to L orthogonal codes are employed for parallel transmission of data by each user. In a mobile phone network system, cell separation can be supported using up to M groups. Despite the large spreading sequence family, the spreading sequence acquisition and tracking are simpler than is the case in DS-CDMA systems.

In preferred embodiments, the despread signal is obtained by inverse filtering of sequence *a[.]* and matched filtering of the phase shifted *b[.]* sequence in convolution with its inverted sequence. For a single path channel, the orthogonality between the parallel data is realised by phase shifts to sequence *b[.]*, whereas in multipath channels, the matched filtering produces a correlation period of 2L. However, unwanted paths are suppressed since the spectrum of *b[.]* is nearly white. Thus, synchronising the receiver with the best path signals, signals from other worse paths are suppressed.

The present invention provides more flexibility suitable for "soft radio" systems. The spreading code may be chosen to provide more capacity in different channels; e.g. a macro-cell with large a propagation time spread may require a larger gap between consecutively offset transmitters and therefore a larger value of L. However, in small pico-cells, larger values of M can be used to accommodate for cells in a small area.

Claims

1. A method of transmitting a signal, the method comprising:-
providing digital data to be transmitted to a remote station as a plurality of parallel bitstreams;
phase modulating said bitstreams with respective orthogonal or substantially orthogonal spectrum spreading signals to produce a plurality of modulating signals;
phase modulating respective instances of a carrier with said modulating signals to produce a plurality to modulated carrier instances; and
summing the modulated carrier instances and transmitting the result of said summation.

2. A method according to claim 1, wherein each spreading signal is produced by phase modulating a common finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence.

3. A method according to claim 1, wherein one of the spreading signals is comprises a finite spreading sequence and the other spreading signals are each produced by phase modulating said finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence.

4. A method according to claim 2 or 3, wherein said cyclic signals are substantially sinusoidal.

5. A method according to claim 4, wherein said cyclic signals are stepped sine waves, each step having the same duration as chips of said spreading sequence.

6. A method according to any one of claims 1 to 5, wherein said spreading sequence *c[.]* is derived from a first code *a[.]* and a second code *b[.]* according to

$$c[n] = \left[a[0]\vec{b}, a[1]\vec{b}, \ldots, a[M-1]\vec{b}\right].$$

7. A method according to claim 6, wherein the Fourier transforms of the first and second codes satisfy:

$$s[t] \leftrightarrow S(e^{j\omega}) \neq 0 \text{ for all } \omega$$

where s and S represent the first and second codes in the time and frequency domains respectively.

8. A method according claim any one of claims 1 to 7, wherein said bitstreams comprise bits of a single digital signal such that groups of bits of said single digital signal are transmitted in parallel.

9. A transmitter comprising:

a source of digital data to be transmitted to a remote station as a plurality of parallel bitstreams;

first means for phase modulating said bitstreams with respective orthogonal or substantially orthogonal spectrum spreading signals to produce a plurality of modulating signals;

second means for phase modulating respective instances of a carrier with said modulating signals to produce a plurality to modulated carrier instances; and

a summer for summing the modulated carrier instances.

10. A transmitter according to claim 9, wherein the first means comprises means for producing each spreading signal by phase modulating a common finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence.

11. A transmitter according to claim 9, wherein the first means comprises means for producing one of the spreading signals by generating a finite spreading sequence and producing the other spreading signals by phase modulating said finite spreading sequence with a respective cyclic signal, said cyclic signals being such that each completes an integer number of cycles in the duration of said spreading sequence.

12. A transmitter according to any one of claim 10 or 11, wherein said cyclic signals are substantially sinusoidal.

13. A transmitter according to claim 12, wherein said cyclic signals are stepped sine waves, each step having the same duration as chips of said spreading sequence.

14. A transmitter according to any one of claims 9 to 13, wherein said spreading sequence *c[.]* is derived from a first code *a[.]* and a second code *b[.]* according to

$$c[n] = \left[a[0]\vec{b}, a[1]\vec{b}, \ldots, a[M-1]\vec{b}\right].$$

15. A transmitter according to claim 14, wherein the Fourier transforms of the first and second codes satisfy:

$$s[t] \leftrightarrow S(e^{j\omega}) \neq 0 \text{ for all } \omega$$

where s and S represent the first and second codes in the time and frequency domains respectively.

16. A transmitter according claim any one of claims 9 to 15, wherein the source of digital data signals includes means for generating said bitstreams from a single digital signal such that groups of bits of said single digital signal are transmitted in parallel.

17. A transmitter according to claim 16, wherein said means for generating said bitstreams comprises a digital signal processor.

18. A transmitter according to any one of claims 9 to 17, wherein the first means comprises a digital signal processor .

19. A transmitter according to any one of claim 9 to 18, wherein the second means comprises a plurality of analogue phase modulators.

20. A mobile phone including a transmitter according to any one of claims 9 to 19.

21. A base station of a mobile phone network including a transmitter according to any one of claims 9 to 19.

22. A method of receiving a signal produced by a method according to claim 1, the method comprising the steps of:-

producing a baseband signal, comprising components corresponding to the modulating signals, from a received rf signal; and

processing the baseband signal by processes adapted to extract the data from each of the modulating signals.

23. A method according to claim 22, wherein at least all but one of said processes comprises:-

phase modulating the baseband signal by the inverse of a respective one of said cyclic signal to produce a first signal;

phase modulating instances of the first signal by respective cyclic signals of the form $e^{j2\pi nP/L}$ where P comprises the set of values in the range 0, ... , L-1, and L is the length of the second code to produce L second signals;

filtering each of said second signals with a filter having a transfer function which is the inverse of the first code to produce respective third signals;

correlating the third signals with corresponding reference signals and summing the results of the said correlations.

24. A method according to claim 22 or 23, including mapping the outputs of said processes onto a transmitted parallel bit pattern using a maximum likelihood algorithm and outputting said parallel bit pattern.

25. A method according to claim 22, 23 or 24, wherein data bits extracted by said processes are combined into a single data signal.

26. A receiver for receiving a signal produced by a method according to claim 1, the receiver comprising:-

rf processing means for producing a baseband signal, comprising components corresponding to the modulating signals, from a received rf signal; and

processing means for processing the baseband signal by processes adapted to extract the data from each of the modulating signals.

27. A receiver according to claim 26, wherein at least all but one of said processes comprises:-

phase modulating the baseband signal by the inverse of a respective one of said cyclic signal to produce a first signal;

phase modulating instances of the first signal by respective cyclic signals of the form $e^{j2\pi nP/L}$ where P comprises the set of values in the range 0, ... , L-1, and L is the length of the second code to produce L second signals;

filtering each of said second signals with a filter having a transfer function which is the inverse of the first code to produce respective third signals;

correlating the third signals with corresponding reference signals and summing the results of the said correlations.

28. A receiver according to claim 26 or 27, wherein the processing means is configured for mapping the outputs of said processes onto a transmitted parallel bit pattern using a maximum likelihood algorithm and outputting said parallel bit pattern.

29. A receiver according to claim 26, 27 or 28, wherein the processing means is configured to combine the extracted data bits into a single data signal.

30. A receiver according to any one of claims 26 to 29, wherein the processing means comprises a digital signal processor.

31. A mobile phone including a receiver according to any one of claims 26 to 30.

32. A base station of a mobile phone network including a receiver according to any one of claims 26 to 30.

33. A mobile phone network including a base station according to claim 32 in communicative relation to a plurality of mobile phones according to claim 20, wherein the mobile phones employ the same carrier frequency and spreading signals for communication with the base station, each mobile phone applying the spreading

signals in a time offset manner relative to the use of the spreading signals by each of the other mobile phones.

34. A method of RS-CTDMA operation in which, for a spreading code of length N=ML,

(a) L orthogonal codes, specified by $\{f_i\}=\{i+\ell*M\}$ ($\ell = 0,\ldots L-1$) for $i\in[0, M-1]$), are used to transmit up to L data bits in parallel for a user in the ith cell;

(b) users within one cell are time-offset by at least L chips to avoid or reduce intracell interuser interference; and

(c) M orthogonal spectral groups are used in different cells.

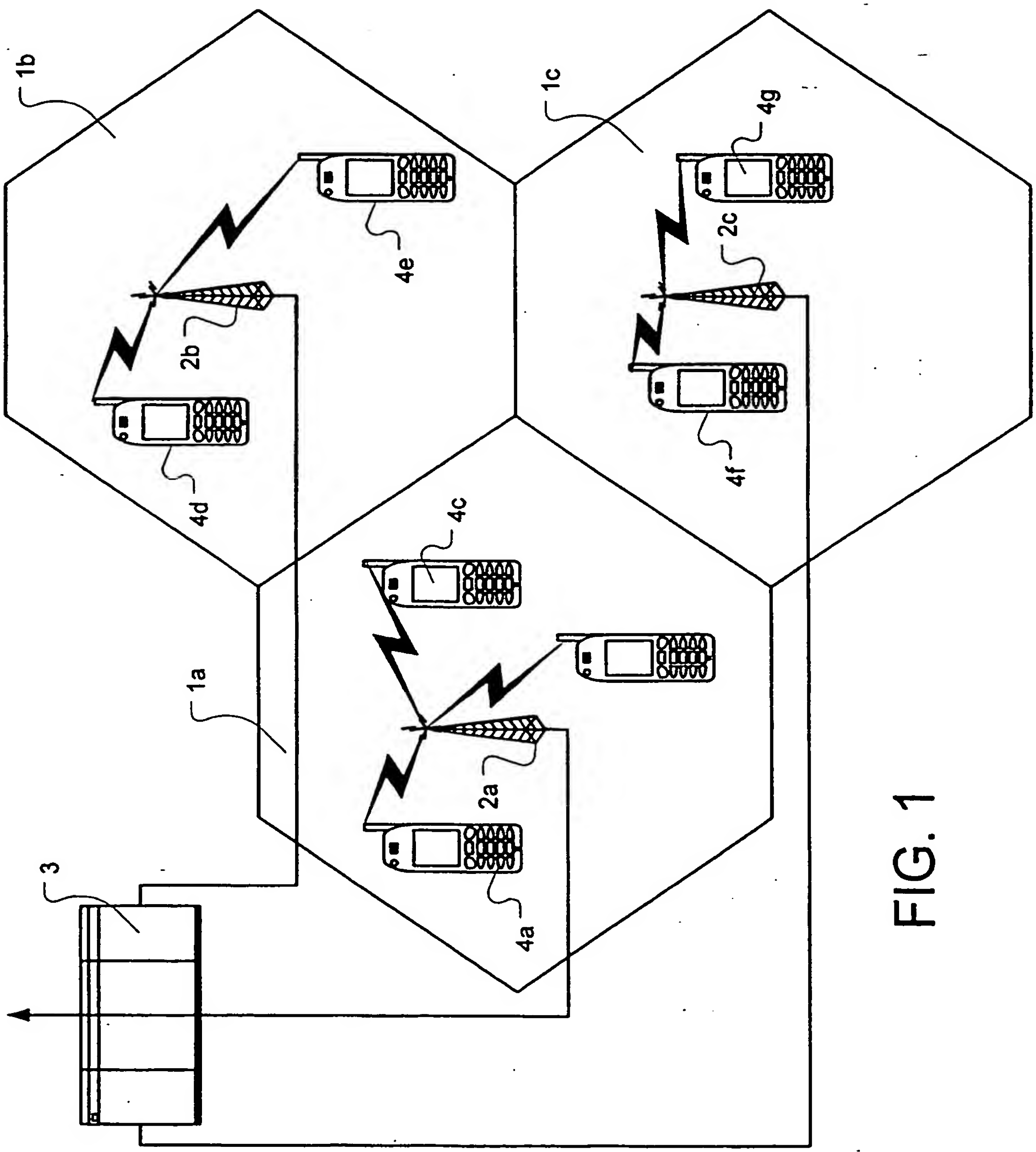


FIG. 1

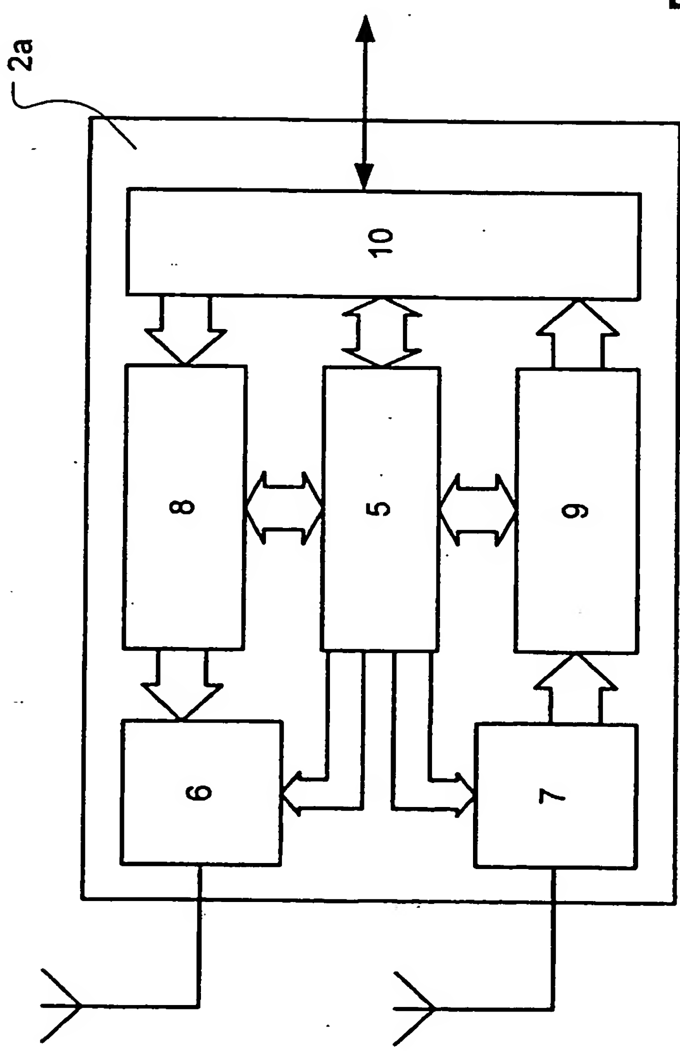


FIG. 2

FIG. 3

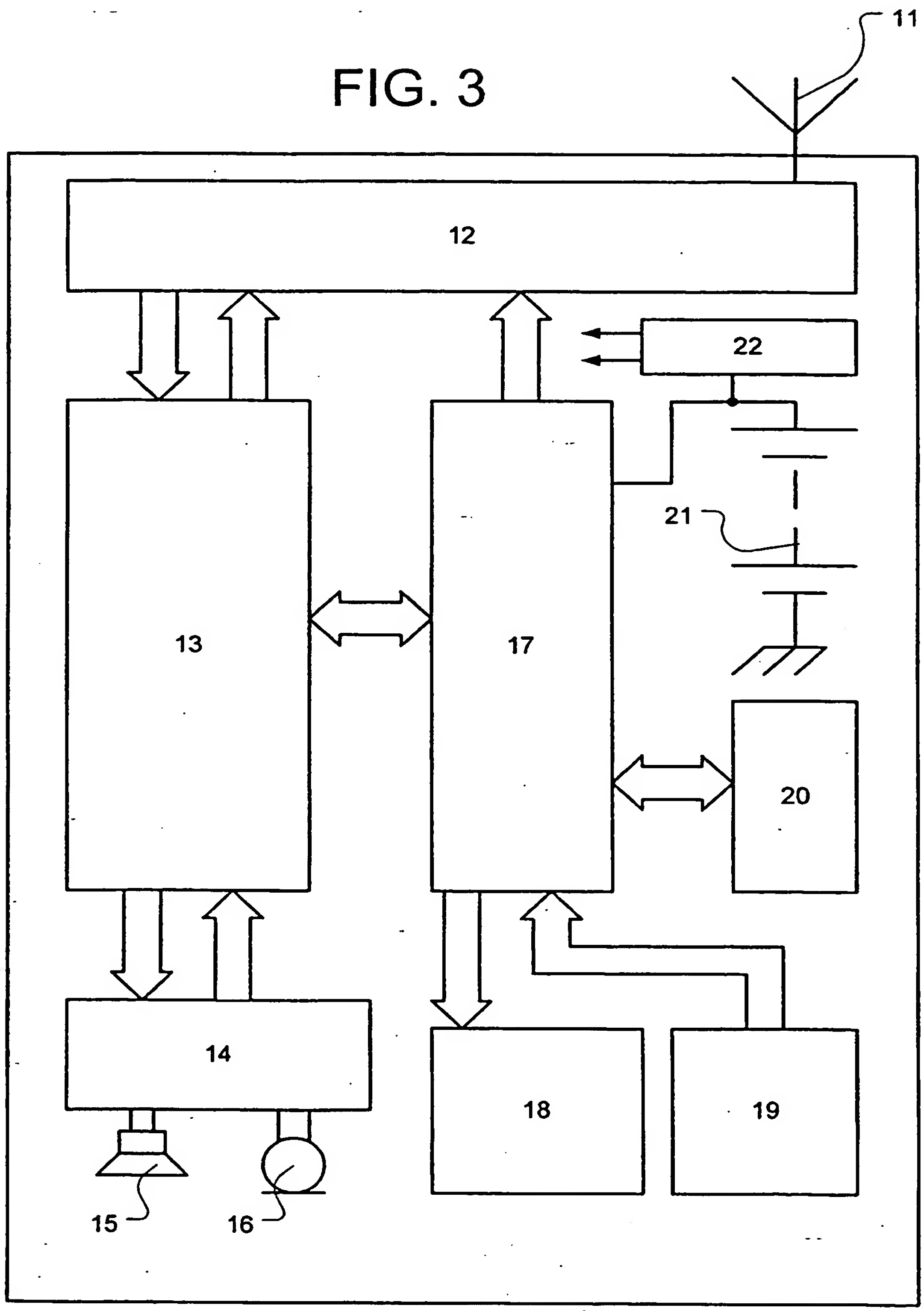
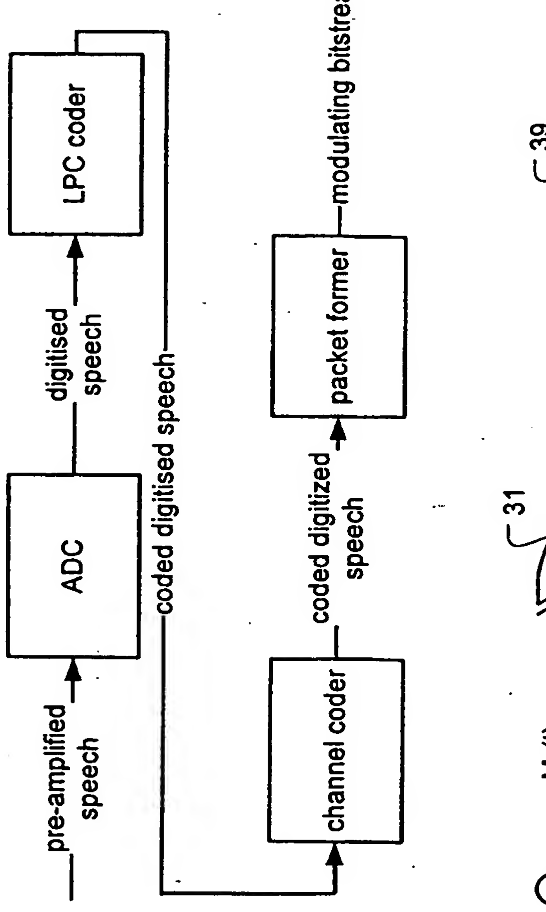


FIG. 4


pre-amplified speech
ADC
digitised speech
LPC coder
coded digitised speech
channel coder
coded digitized speech
packet former
modulating bitstream
serial-to-parallel converter
$M_0(t)$
$M_1(t)$
$M_2(t)$
$M_3(t)$

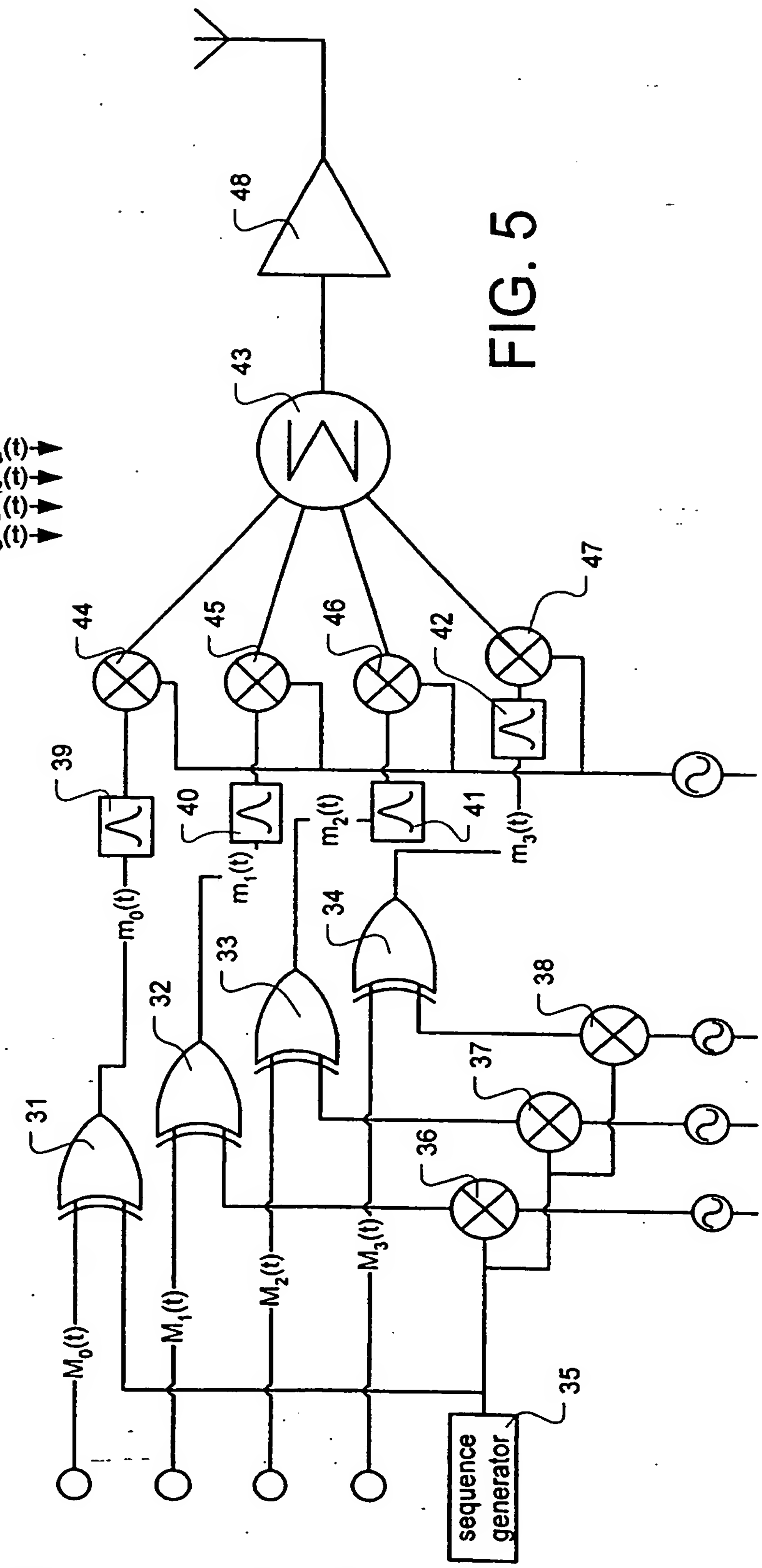

$M_0(t)$
$M_1(t)$
$M_2(t)$
$M_3(t)$
$m_0(t)$
$m_1(t)$
$m_2(t)$
$m_3(t)$
sequence generator
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FIG. 5

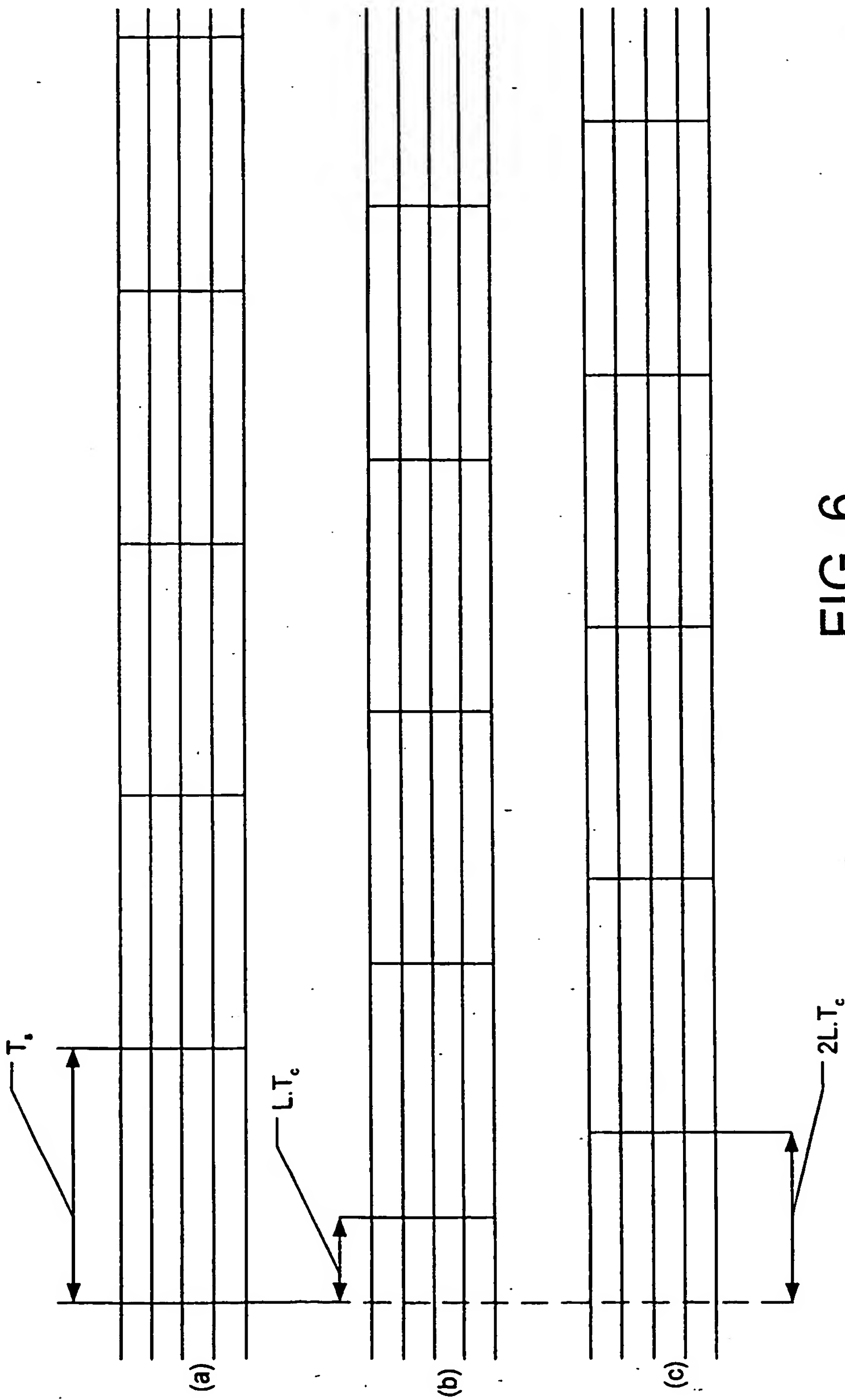


FIG. 6

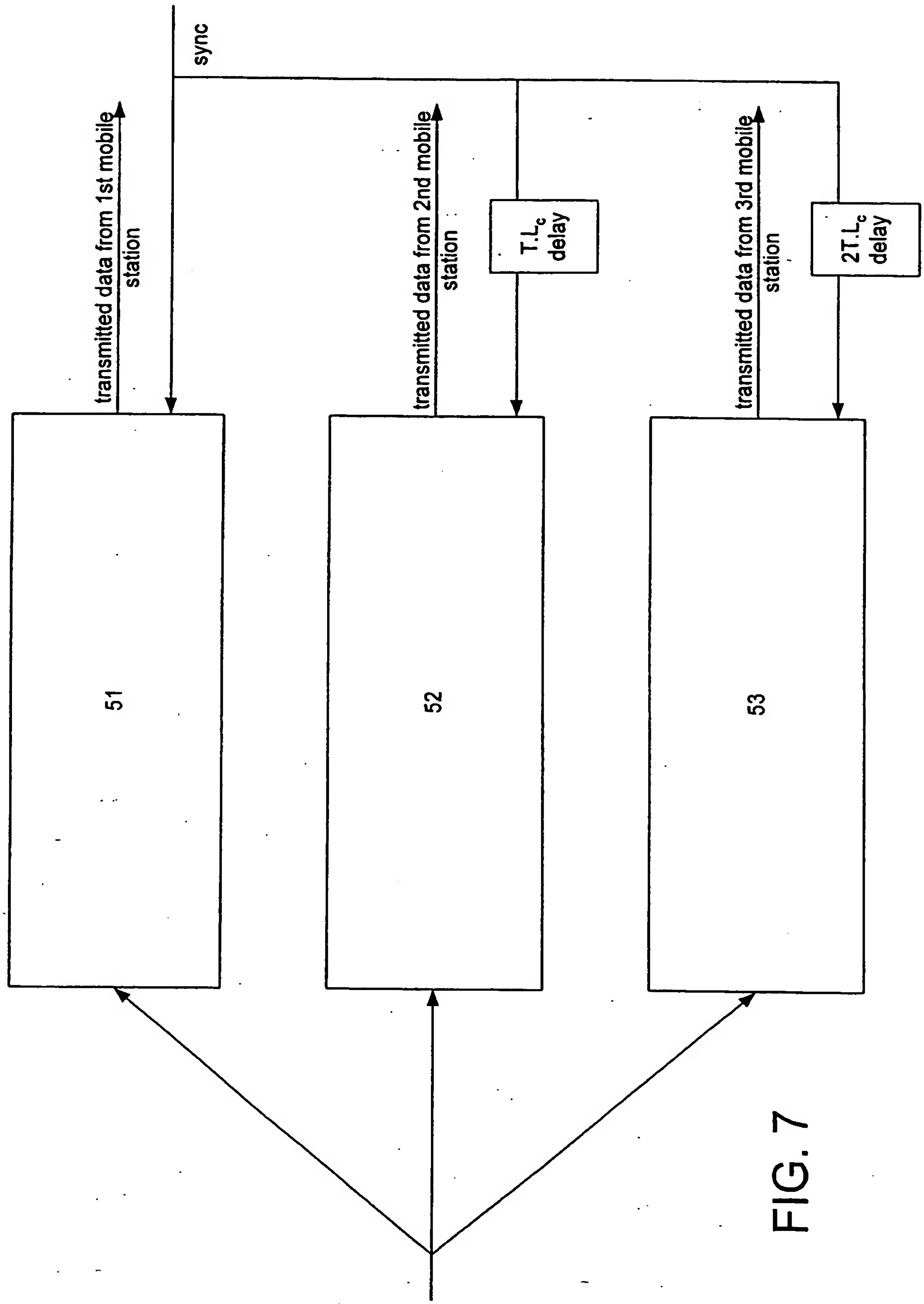
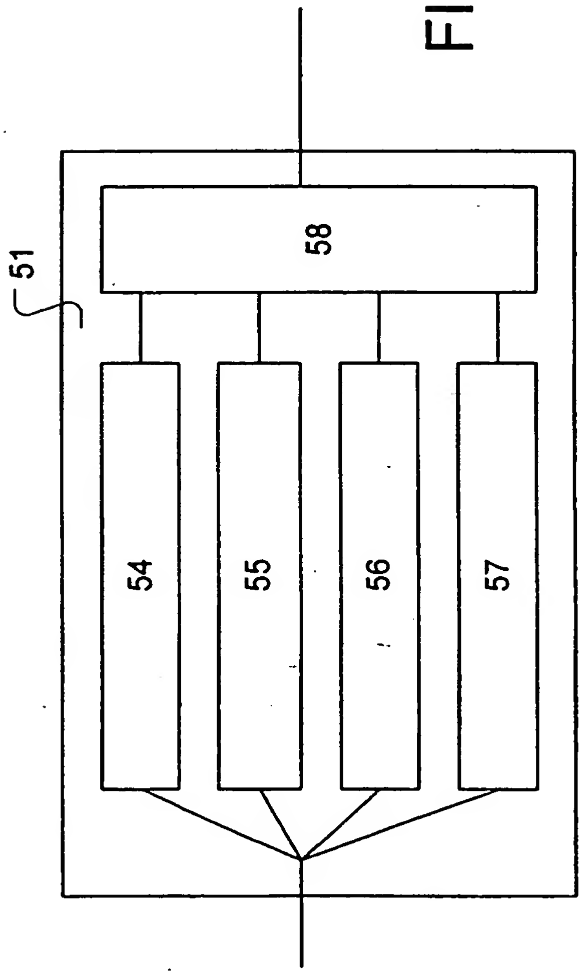

sync
transmitted data from 1st mobile station
transmitted data from 2nd mobile station
T.L$_c$ delay
transmitted data from 3rd mobile station
2T.L$_c$ delay
51
52
53

FIG. 7

FIG. 8



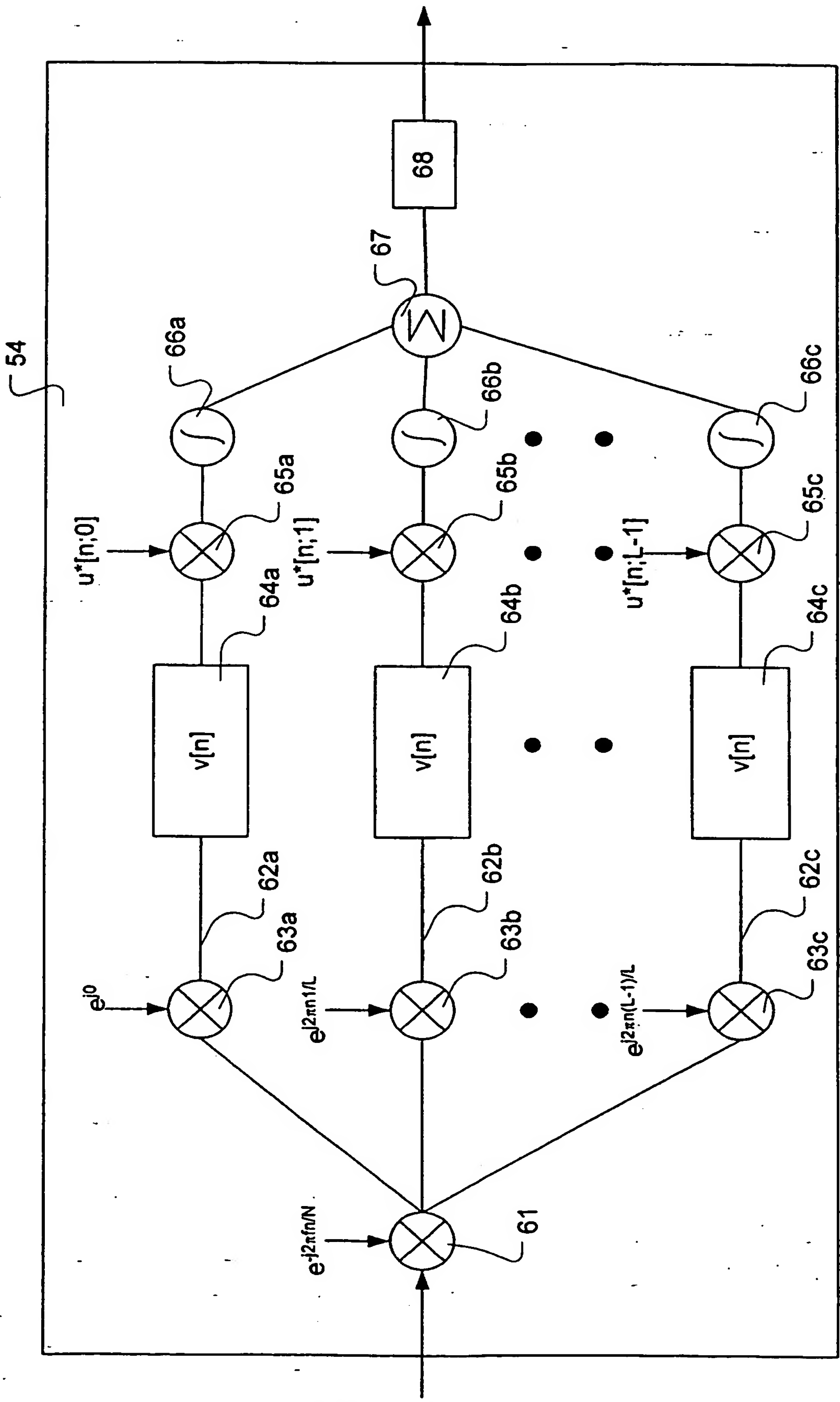

54
61
62a
62b
62c
63a
63b
63c
64a
64b
64c
65a
65b
65c
66a
66b
66c
67
68
v[n]
v[n]
v[n]
u*[n;0]
u*[n;1]
u*[n;L-1]
sync

FIG. 9

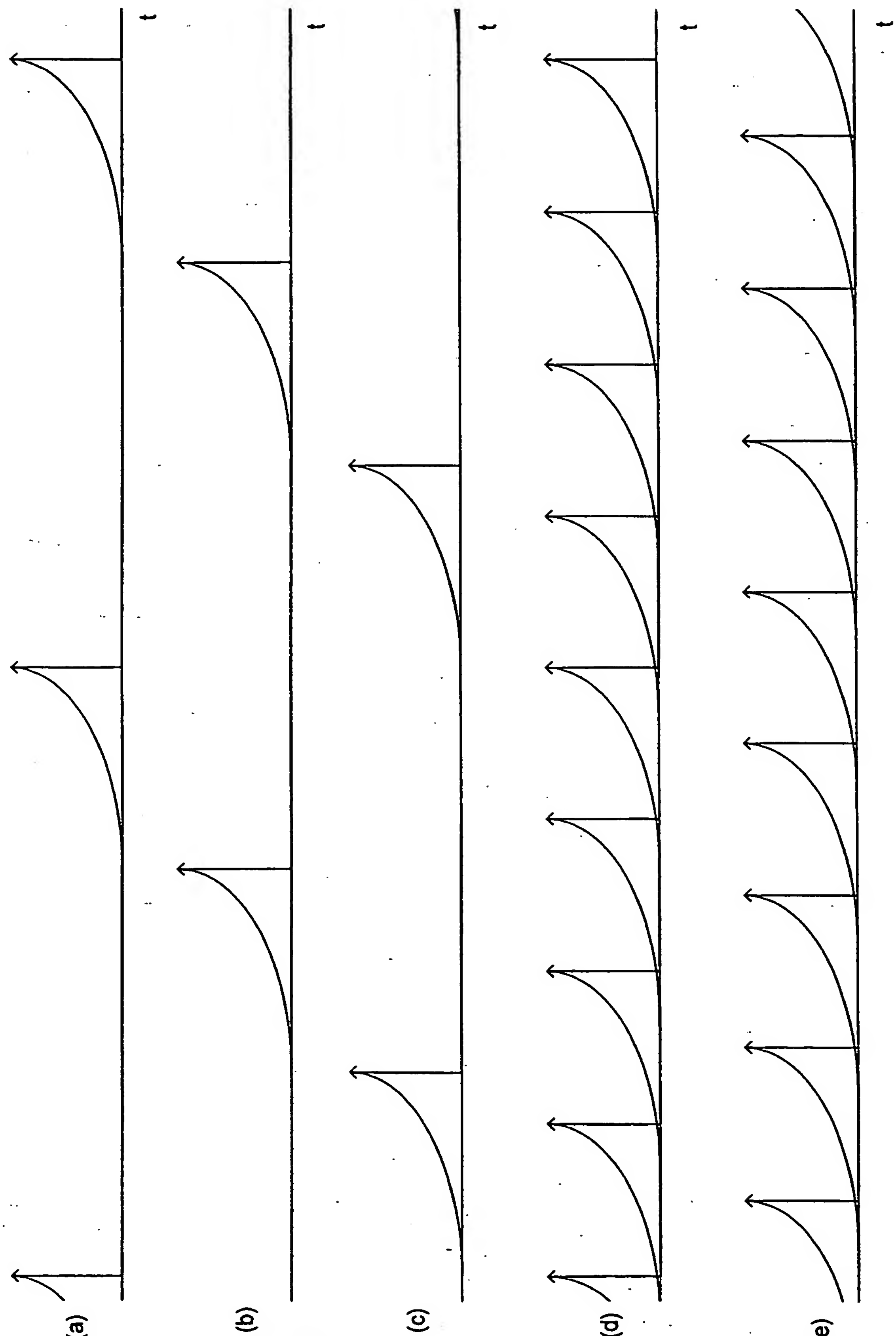


FIG. 10

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 07 36463	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 00/03600	International filing date *(day/month/year)* 20/09/2000	(Earliest) Priority Date *(day/month/year)* 20/09/1999
Applicant NOKIA MOBILE PHONES LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 6 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :
      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [X] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,
   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 5
   [ ] as suggested by the applicant.
   [X] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-19

   Method and apparatus for transmitting a plurality of parallel bitstreams to a remote station by phase-modulating instances of a carrier, said bitstreams modulated with orthogonal spectrum spreading signals.

   1.1. Claims: 2,3,4,5,8,910,11
   Use of cyclic signals or synusodal waveforms for modulating the spreading sequences.

   1.2. Claims: 6,7,12,13
   Specifications of the chosen spreading codes.

   1.3. Claim : 15
   Digital signal processor for generating said bitstreams.

   1.4. Claim : 16
   Digital signal processor for phase-modulating said bitstreams.

   1.5. Claim : 17
   Use of analogue phase modulators for phase-modulating the carrier.

   1.6. Claim : 18
   Mobile phone including the transmitter.

   1.7. Claim : 19
   Base station including the transmitter.

2. Claims: 20-31

   A method and a receiver for receiving spread-spectrum signals, producing a baseband signal, and extracting data from the processed signals.

3. Claim : 32

   Characteristics of L orthogonal codes used to transmit up to L data bits in parallel. Specifications of the time offset between users within one cell and of the numbre of different

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

orthogonal spectral groups used in the system.

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

INTERNATIONAL SEARCH REPORT

International Application No
P[illegible]GB 00/03600

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B1/707 H04J13/00 H04L5/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04J H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, PAJ, WPI Data, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 758 823 A (SHARP KK) 19 February 1997 (1997-02-19)	14-16, 18,19,66
Y	abstract; figure 1 page 8, line 38 - line 55 ---	1,77
X	I C -L ET AL: "MULTI-CODE CDMA WIRELESS PERSONAL COMMUNICATIONS NETWORKS" PROCEEDINGS OF THE CONFERENCE ON COMMUNICATIONS (ICC),US,NEW YORK, IEEE, 18 June 1995 (1995-06-18), pages 1060-1064, XP000533158 ISBN: 0-7803-2487-0 page 1061, left-hand column, paragraph 2 page 1062, left-hand column, paragraph 2	6,12
Y	figures 1,2 --- -/--	1,77

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 June 2001	27. 06. 2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Amadei, D

5

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WADA T ET AL: "A NEW M-ARY SPREAD-SPECTRUM MULTIPLE-ACCESS SCHEME IN THE PRESENCE OF CARRIER FREQUENCY OFFSET" IEICE TRANSACTIONS ON FUNDAMENTALS OF ELECTRONICS, COMMUNICATIONS AND COMPUTER SCIENCES,JP,INSTITUTE OF ELECTRONICS INFORMATION AND COMM. ENG. TOKYO, vol. E79-A, no. 9, 1 September 1996 (1996-09-01), pages 1415-1421, XP000679633 ISSN: 0916-8508 page 1415, right-hand column, paragraph 2 -page 1416, right-hand column, paragraph 3 figures 1,5	2,3,8,9
X	US 5 790 591 A (GOLD ROBERT ET AL) 4 August 1998 (1998-08-04) column 12, line 34 - line 41; figures 4B,4C column 16, line 22 - line 32 column 13, line 34 - line 54 column 15, line 15 - line 29; figures 7A,7B,7C column 15, line 40 - line 50 column 15, line 58 -column 16, line 7; figure 8	20-27, 29,30
X	US 5 881 056 A (BRINK STEPHAN TEN ET AL) 9 March 1999 (1999-03-09) abstract; figures 1,4	20,23, 24,27-30
Y	RUPRECHT J ET AL: "CODE TIME DIVISION MULTIPLE ACCESS: AN INDOOR CELLULAR SYSTEM" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY SOCIETY CONFERENCE (VTSC),US,NEW YORK, IEEE, vol. CONF. 42, 10 May 1992 (1992-05-10), pages 736-739, XP000339889 ISBN: 0-7803-0673-2 abstract; figures 1,2 page 737, left-hand column, paragraph II	32
Y	WU Y ET AL: "RS-CDMA: A QUASI-SYNCHRONOUS CMDA SCHEME TO SUPPORT UPLINK OPERATION OF MOBILE COMMUNICATION" PHOENIX, ARIZONA, NOV. 3 - 8, 1997,NEW YORK, IEEE,US, 3 November 1997 (1997-11-03), pages 619-623, XP000737613 ISBN: 0-7803-4199-6 abstract; figure 1 page 619, right-hand column, paragraph II	32

5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/03600

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0758823 A	19-02-1997	JP 9055714 A	25-02-1997
		JP 9247123 A	19-09-1997
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		EP 1067724 A	10-01-2001
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		US 5724383 A	03-03-1998
		US 5761239 A	02-06-1998
US 5881056 A	09-03-1999	NONE	

PATENT COOPERATION TREATY

RECEIVED
03 DEC 2001

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INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

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LONDON EC1A 7DH
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

		Date of mailing *(day/month/year)* 30.11.2001
Applicant's or agent's file reference 07 36463		**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/03600	International filing date *(day/month/year)* 20/09/2000	Priority date *(day/month/year)* 20/09/1999
Applicant NOKIA MOBILE PHONES LIMITED et al.		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 07 36463	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB00/03600	International filing date *(day/month/year)* 20/09/2000	Priority date *(day/month/year)* 20/09/1999
International Patent Classification (IPC) or national classification and IPC H04B1/69		
Applicant NOKIA MOBILE PHONES LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
18/04/2001	30.11.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Aquilani, D Telephone No. +49 89 2399 7981

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
   Description, pages:

   1-19 as originally filed

   Claims, No.:

   1-34 as originally filed

   Drawings, sheets:

   1/9-9/9 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2-8, 10-21, 30-34
	No:	Claims	1, 9, 22-29
Inventive step (IS)	Yes:	Claims	34
	No:	Claims	1-33
Industrial applicability (IA)	Yes:	Claims	1-34
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

D1: I C -L ET AL: 'MULTI-CODE CDMA WIRELESS PERSONAL COMMUNICATIONS NETWORKS' PROCEEDINGS OF THE CONFERENCE ON COMMUNICATIONS (ICC),US,NEW YORK, IEEE, 18 June 1995 (1995-06-18), pages 1060-1064, XP000533158 ISBN: 0-7803-2487-0.

D2: WU Y ET AL: 'RS-CDMA: A QUASI-SYNCHRONOUS CMDA SCHEME TO SUPPORT UPLINK OPERATION OF MOBILE COMMUNICATION' PHOENIX, ARIZONA, NOV. 3 - 8, 1997,NEW YORK, IEEE,US, 3 November 1997 (1997-11-03), pages 619-623, XP000737613 ISBN: 0-7803-4199-6.

D3: RUPRECHT J ET AL: 'CODE TIME DIVISION MULTIPLE ACCESS: AN INDOOR CELLULAR SYSTEM' PROCEEDINGS OF THE VEHICULAR TECHNOLOGY SOCIETY CONFERENCE (VTSC),US,NEW YORK, IEEE, vol. CONF. 42, 10 May 1992 (1992-05-10), pages 736-739, XP000339889 ISBN: 0-7803-0673-2.

D4: EP-A-0 758 823 (SHARP KK) 19 February 1997.

2. *Claims 1-8*

2.1 Insofar as the application can be understood (see section VIII), the document D1 discloses (the references in parentheses applying to this document):

A method of transmitting a signal, the method comprising:

- providing digital data to be transmitted to a remote station as a plurality of parallel bitstreams (fig. 2: output of the S/P converter);
- phase modulating said bitstreams with respective orthogonal or substantially orthogonal spectrum spreading signals (fig. 2: the C_i codes; according to Eq. (1) they are orthogonal each other. Multiplying the bitstreams by C_i results in

modulating the polarity of the bitstreams, i.e. in making their phase to be 0° or 180°) to produce a plurality of modulating signals (fig. 2 the I and Q branches of the resulting bit stream);

- phase modulating respective instances of a carrier ($\cos\omega_0 t$, $\sin\omega_0 t$) with said modulating signals (I and Q streams) to produce a plurality of modulated carrier instances;
- and summing the modulated carrier instances and transmitting the result of said summation (fig. 2 the rightmost adder downstream of the I and Q carrier modulators).

2.2 The subject-matter of claim 1 is therefore not new (Article 33(2) PCT).

2.3 As far as the application can be at the present understood, dependent claims 2-8 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the EPC with respect to novelty and inventive step, the reasons being as follows: when combined with their relevant independent claims, even if they could characterise new features, they would be not inventive, since such amendments would be obvious to the person skilled in the art.

In particular:

2.4 Document D2 anticipates the additional steps/features of claims
2-5 (see eq. 6),
6 (see eq. 5),

2.5 the additional steps/features of claim 7 are obvious since the person skilled in the art would select finite code sequences for feasibility reasons and it is well known that the Fourier transform of a finite signal has an "infinite" spectrum (i.e. $S(\omega)\neq0$ for all ω).

2.6 The additional steps/features of claim 8 are known from D1 (see fig.2).

2.7 Therefore a person skilled in the art would provide these features/steps with corresponding effect the a method as known from document D1 without the exercise of inventive step.

3. *Claims 9-21*

3.1 The subject matter of independent claim 9 appears to correspond to the one disclosed by claim 1. Hence the argumentation provided for claim 1 correspondingly applies to claim 9 whose subject matter is, therefore, not new.

3.2 For the same reasons as given for claims 2-8, the dependent claims 10-16 are not considered to be inventive.

3.3 The additional steps/features of claims 17-21 are matter of normal design procedure and they are therefore not inventive.

4. *Claims 22-25*

4.1 Insofar as the application can be understood (see section VIII), the document D2 discloses (the references in parentheses applying to this document):

a method of receiving a signal produced by a method according to claim 1, the method comprising the steps of:
- producing a baseband signal, comprising components corresponding to the modulating signals, from a received rf signal (input signal in fig. 1);
- and processing the baseband signal by processes adapted to extract the data from each of the modulating signals (different receiving paths of fig.1).

4.2 The subject-matter of claim 1 is therefore not new (Article 33(2) PCT).

4.3 D2 fully anticipates also the dependent claims
23 (see fig. 1),
24 (see eq. 26),
and 25 (see fig. 1)

which are therefore not new.

5. *Claims 26-33*

5.1 The subject matter of independent claim 26 appears to correspond to the one disclosed by claim 22. Hence the argumentation provided for claim 22 correspondingly applies to claim 26 whose subject matter is, therefore, not new.

5.2 For the same reasons as given for claims 23-25, the dependent claims 27-29 are not considered to be new.

5.3 The additional steps/features of claims 30-33 are matter of normal design procedure and they are therefore not inventive.

6. *Claim 34*

6.1 Insofar as the application can be understood (see section VIII), the document D2 is regarded as being the closest prior art to the subject-matter of claim 34, and shows (the references in parentheses applying to this document):

- a method of RS-CTDMA operation in which, for a spreading code of length N=ML where:
  L orthogonal codes, specified by $f_i=i+\ell*M$ ($\ell = 0,\dots L-1$) for $i\in[0, M-1]$, are used to transmit up to L data bits in parallel for a user in a cell (see passage in Section III of D2);

- users within one cell are time-offset by at least L chips to avoid or reduce intracell interuser interference (implicit: in the paper introduction, Section I, it is stated that the number of users is bounded to N/Δ, where Δ is the users time offset and N is the length of the spreading sequence; in Section III it is stated that "... for a spreading code of length N=ML ... M users having zero cross-talk can be accommodated ...", thus leading that: number of users=M= $N/\Delta=ML/\Delta \Rightarrow \Delta=L$).

6.2 The subject-matter of claim 34 therefore differs from this known D2 in that:

- M orthogonal spectral groups are used in different cells

6.3 The subject-matter of claim 34 is therefore novel (Article 33(2) PCT).

6.4 The problem to be solved by the present invention may therefore be regarded as how to improve the cell separation in a mobile phone network system (descr. pag. 18, lines 12-13).

6.5 The solution to this problem proposed in claim 34 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons:

6.5.1 Document D1 discloses a Multi Code - Code Division Multiple Access (MC-CDMA) system to provide wireless communication services at variable rates dynamically matched to the users' needs.

6.5.2 Document D2 discloses a despreading scheme for a Rotated Spectrum - Code Division Multiple Access System (RS-CDMA).

6.5.3 Document D3 discloses a wideband communications system for indoor cellular applications using Code/TIme Division Multiple Access (CTDMA).

6.5.4 Document D4 discloses a Spread Spectrum communication system splitting a single datastream in multiple parallel CDMA channels.

6.5.5 In none of the above cited documents indications are given which would lead the skilled person to provide the features of claim 34 to solve the aforementioned technical problem.

<u>Re Item VII</u>

Certain defects in the international application

7. Independent claim 34 is not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D2) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

8. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

9. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1-D4 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the international application

10. The scope of protection of claims 6, 7, 14, 15, 27, 34 is unclear because the meaning of the symbols and operators used in the mathematical formulas introduced thereto is not explained.

11. In the feature c) of claim 34 is not clear whether the M orthogonal special groups are used in each cell or, instead, in each cell a single group is used and then the total number of different groups is M.